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Snead, Douglas Lee.

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CYBERNETIC AIRCRAFT MAINTENANCE MANAGEMENT

DOUGLAS LEE SNEAD

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CYBERNETIC AIRCRAFT MAINTENANCE MANAGEMENT

By

Douglas Lee Snead

Bachelor of Science

United States Naval Academy, 1953

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Thesis directed by

Karl E. Stromsem, Ph. D.

Professor of Public Administration

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INTRODUCTION

The Problem

Aircraft maintenance is a costly, complex, technical business. The problems involved in management of this business are staggering. There are hundreds of thousands of parts in each modern airplane over which rigid controls must be maintained. Aircraft, aircraft parts, aircraft maintenance equipment and aircraft mechanics are expensive. Technical innovations to aircraft systems and parts are a constantly reoccurring problem. Everything associated with aircraft is technical and costly.

In one airplane alone inefficient management can be translated into a multimillion dollar investment idle and useless. Maintenance mismanagement could result in the entire investment being destroyed along with many lives. Maintenance management must make advances to keep pace with the rapid advance of technology of the aircraft itself and the soaring costs of its maintenance.

Within the last two decades there has been rapid and extensive progress in the application of cybernetic

techniques to management problems.[1] Two areas of activity involved are: (1) the concept of production, that is, automation; and (2) the use of computers for mass integrated data processing and decision-making.

Are aircraft maintenance managers using cybernetics to solve problems of management? What kind of techniques and equipment are managers developing and using and what is the impact of this technology upon aircraft maintenance?

Scope and Treatment

This study was undertaken to answer these questions and to develop a non-technical paper giving a general overview of cybernetics in aircraft maintenance management. Any one technique or system discussed would lend itself to an investigation of greater effort than this entire paper.

The reader will possibly note that problems and their treatment are frequently recognized in terms of dollars. This approach is understandable in view of the writer's background and the academic application of this study.

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[1] Generally defined, cybernetics is the comparative study of the automatic control system formed by the nervous system and brain, and by mechano-electrical systems and devices.

The subject was researched through extensive readings in books, periodicals, studies and reports. The writer corresponded with top officials in maintenance and management of American Airlines, United Air Lines, Continental Air Lines, Trans World Airlines, Delta Air Lines, Pan American World Airways, National Airlines and Trans-Canada Air Lines. Military officers, Federal Aviation Authority officials, representatives of aircraft companies and manufacturers of computer equipment were interviewed. To a lesser extent the writer called upon his own knowledge and background as a military pilot and former squadron maintenance officer.

The paper begins with a brief sketch of military applications of cybernetics in maintenance management. Investigation proved military aviation a late entry into the field -- fully ten years behind the commercial airlines. Basically military aviation is just recognizing its management problems and the potential of cybernetics for control. The airlines have been making profits on these applications for a decade. Therefore, the remainder of the study is in the maintenance activities of the United States commercial carrier.

Chapter two outlines maintenance costs within the airlines and how cybernetic systems can help. This chapter is an introduction to the airline maintenance

problem and was developed primarily from correspondence with officials at Continental Air Lines, Inc.

The third chapter deals with computer control over the preventive maintenance concept now employed by most airlines. This application is perhaps the most significant application of cybernetics to the airline maintenance problem to date. Chapter four offers a specific example of this innovation -- Trans World Airlines' computer system.

Chapter five describes the evolution and application of the "critical path analysis" at United Air Lines Base Overhaul -- developed from the familiar management tool -- PERT.

Chapter six reviews what automatic maintenance equipment is available now and what direction should be taken in this area. Chapter seven discusses the flight recorder as the solution to the "hours flown" concept of management and its significance in cybernetic management. The last chapter, eight, summarizes and critiques the approaches to aircraft maintenance problems and what gains have been realized.

It is not the thesis of this study that cybernetics is a panacea for aircraft maintenance management problems.

CHAPTER I

MILITARY APPLICATIONS

Military aviation currently is turning its technical attention to more sophisticated aircraft maintenance management systems to bring problems in focus and costs under control. The Department of Defense claims they are spending about 25 per cent of the defense budget and the efforts of a million defense people on maintenance of military equipment.[1] Even in the absence of an adequate cost accounting system, it is safe to estimate that of this $12 billion that $6 billion is used on aircraft maintenance.

Cost, however, is not the main reason for intensified emphasis on maintenance. National security comes first, then economizing. Equipment readiness is of primary consideration toward overall readiness. No longer is there a clear distinction between peace and war. Constant readiness is required. Cuba has shown that we must fight future wars with what we've got now, not with

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[1] Wagner, Joe, "Maintenance Is the Key to Our Defense Posture," Armed Forces Management, Jan. 1964, p. 20.

what we may get from production lines tomorrow. Maintenance is the key to our defense posture.

Labor Accounting -- Data Collection

In July 1962 the Strategic Air Command reported it had sent some 45 additional B-52 aircraft and 31 KC-135 tankers to the ready line -- the result of a relatively new maintenance management program.[1]

This Air Force Maintenance Management System, as outlined in Air Force Manual 66-1, adopts a twofold system to manage resources. An exception manpower accounting system is used to identify and analyze the labor force and a maintenance data collection system is used to identify production and offer a technical analysis of equipment.

First, consider the data collection system. This system provides for maintenance data collection by means of work cards (see Figure 1) furnished to activities whereupon pertinent information is recorded by code as work is performed. The information is then extracted and machine processed into punched cards. The punched cards

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[1] Bamford, Hal, "How Good Is Maintenance Management," Armed Forces Management, Jan. 1964, p. 23.

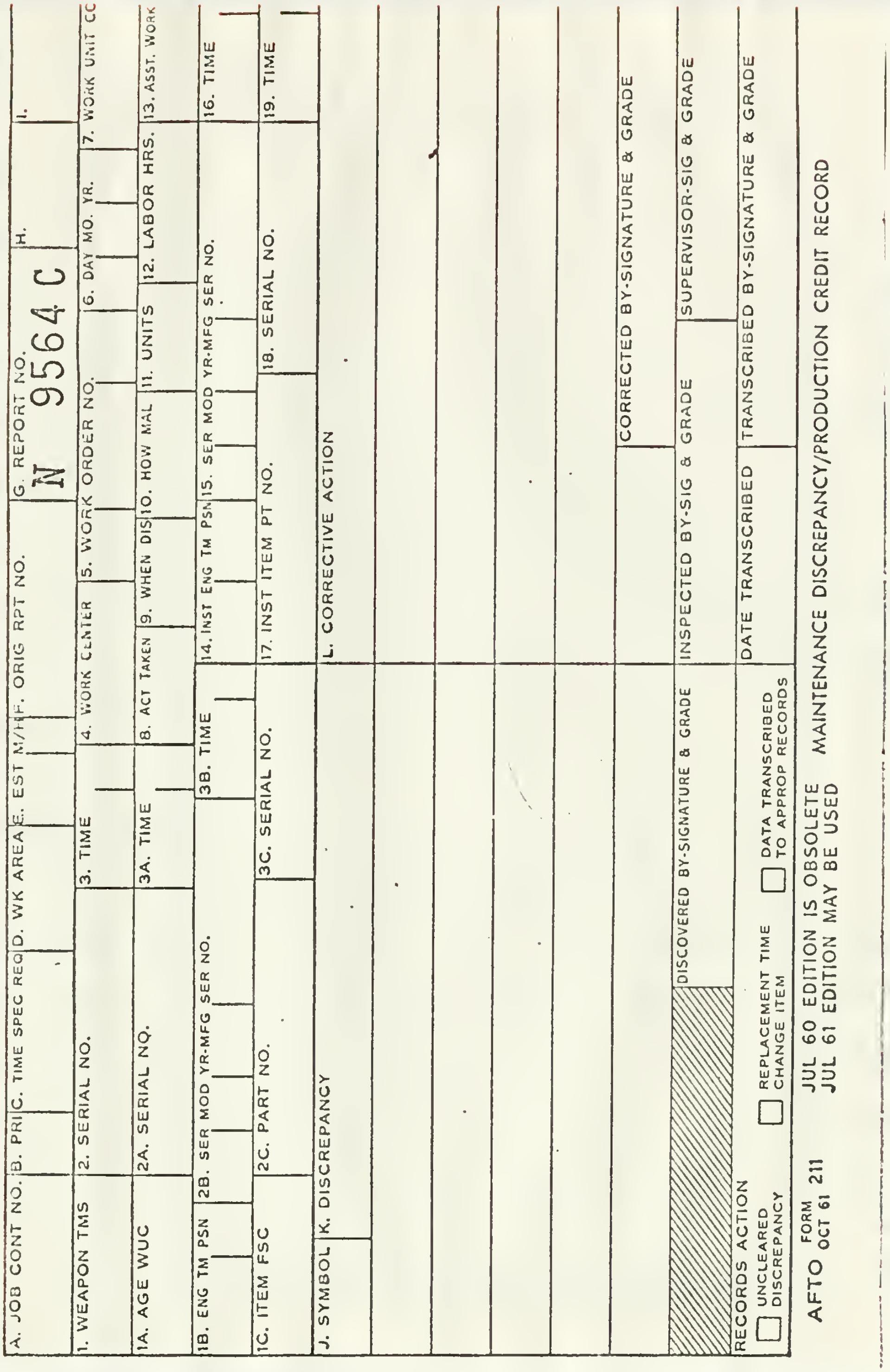

Figure 1.--Maintenance Discrepancy/Production Credit Record, USAF Form 211

can then be fed into electronic data processing equipment for analysis and summaries.[1]

A separate accounting system is utilized for man-hour reporting. The system is based upon the "exception" principle since each deviation from normal duty must be accounted for. Work centers are charged with labor by normal duty hours. Deviations from normal maintenance functions as reported by Daily Exception Cards (see Figure 2) are used to adjust labor changes. The results reflect the true number of man-hours consumed within each maintenance activity.[2] In this manner close surveillance and control is provided for a large segment of maintenance -- labor.

Other Evaluations

The Navy began a study and evaluation of a maintenance system in August 1963.[3] The purpose of this project was to recommend implementing action to achieve a standard maintenance planning and control system through electronic data processing of information. The principle and procedures of the Air Force system described above

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[1]U.S. Air Force, Maintenance Management, Air Force Manual 66-1, 1 Sept. 1962, U.S. Government Printing Office, Chapter 9.

[2]Ibid., Chapter 8.

[3]U.S. Navy, Standard Navy Maintenance Management System, OPNAV 4700.16A, 1 August 1963.

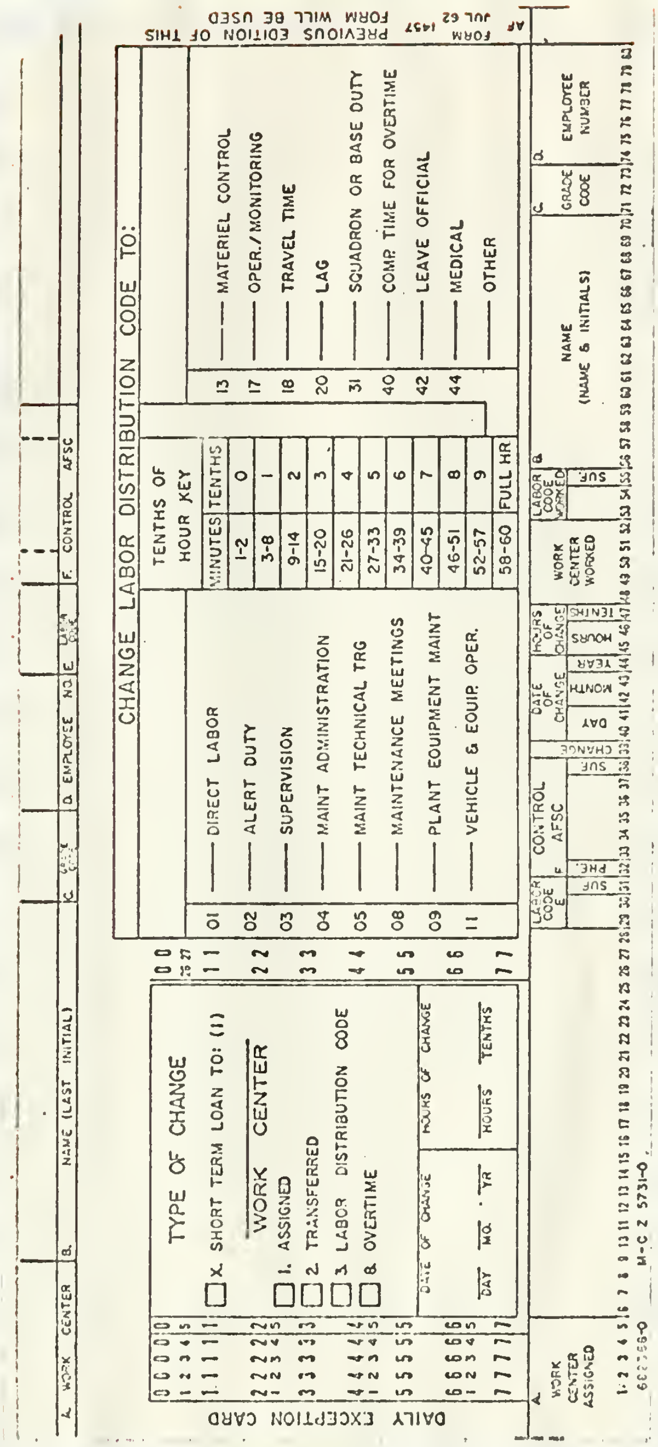

Figure 2.--Man-hour Exception Card, USAF Form 1457

were recognized as adaptable to Navy requirements.[1] Evaluation and development of this system, as well as others, is in progress at this time.

The Army examined the Air Force system in 1963 and adopted salient features with minor changes. The Marine Corps follows Navy operating procedures.

Cybernetic Systems

Essentially all of these systems are to provide maintenance management with information -- information that is timely and meaningful for decisions and control. Through electronic data processing these systems can provide maintenance management with information as to what production jobs are performed by the manpower available for direct labor in each work center. In addition to what is done, the system provides data as to how many direct man-hours are expended on each job; why each repair is required; when the malfunction was discovered; and what work center accomplished the work. All maintenance jobs are recorded in such a manner that comprehensive data is available for analysis of failure rates versus operation time; malfunctions related to inspection periods;

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[1]Within aviation the adaptation is recognized as comparatively direct. Both Air Force and Navy systems have been and are being developed for general maintenance management and are not restricted to aviation maintenance management.

reliability expectancies for systems and components; and frequency and volume of malfunctions related to when discovered.

This information, fed into a central control point, permits comparisons and analysis by electronic data processing systems to be made from the basic data collected. It permits managers a timely overall picture from which to base decisions. Summary data accumulated over a period of time can be used for manpower planning; labor distributions; tooling and equipment needs; budget computations; and cost analysis. Maintenance managers can use this data for decisions regarding inspection and maintenance requirements; life expectancy; time change requirements; justification for modification programs; master repair schedules; deficiency analysis; costs, and parts and components needs.

These techniques are valuable management tools. Maintenance management, however, is evolving slowly in the military in comparison with commercial aviation. Subsequent chapters will be devoted to investigation of cybernetic maintenance management progress in U.S. airlines.

CHAPTER II

AIRLINE MAINTENANCE COSTS -- WHAT CYBERNETICS CAN DO

The scheduled airlines of the United States spend almost two-thirds of a billion dollars annually in maintaining their aircraft. In an industry whose profit margins are small, lowering of these costs can be vitally important. A 10 per cent decrease in maintenance costs would have produced a 60 per cent increase in after taxes profit for the industry for 1962.[1] The impact of these figures point out the necessity of considering, "Where does the maintenance money go?" before evaluating any aircraft maintenance management techniques or systems.

Direct Costs

In broad terms, maintenance costs may be classified as direct and indirect. Figure 3A illustrates that part of the maintenance dollar which goes to direct costs. These are the costs of the productive labor and materials used in the maintenance work on the airframe

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[1] Letter from Alexander Damm, Vice President Finance, Continental Air Lines, Inc., Los Angeles, Calif., 9 Dec. 1963.

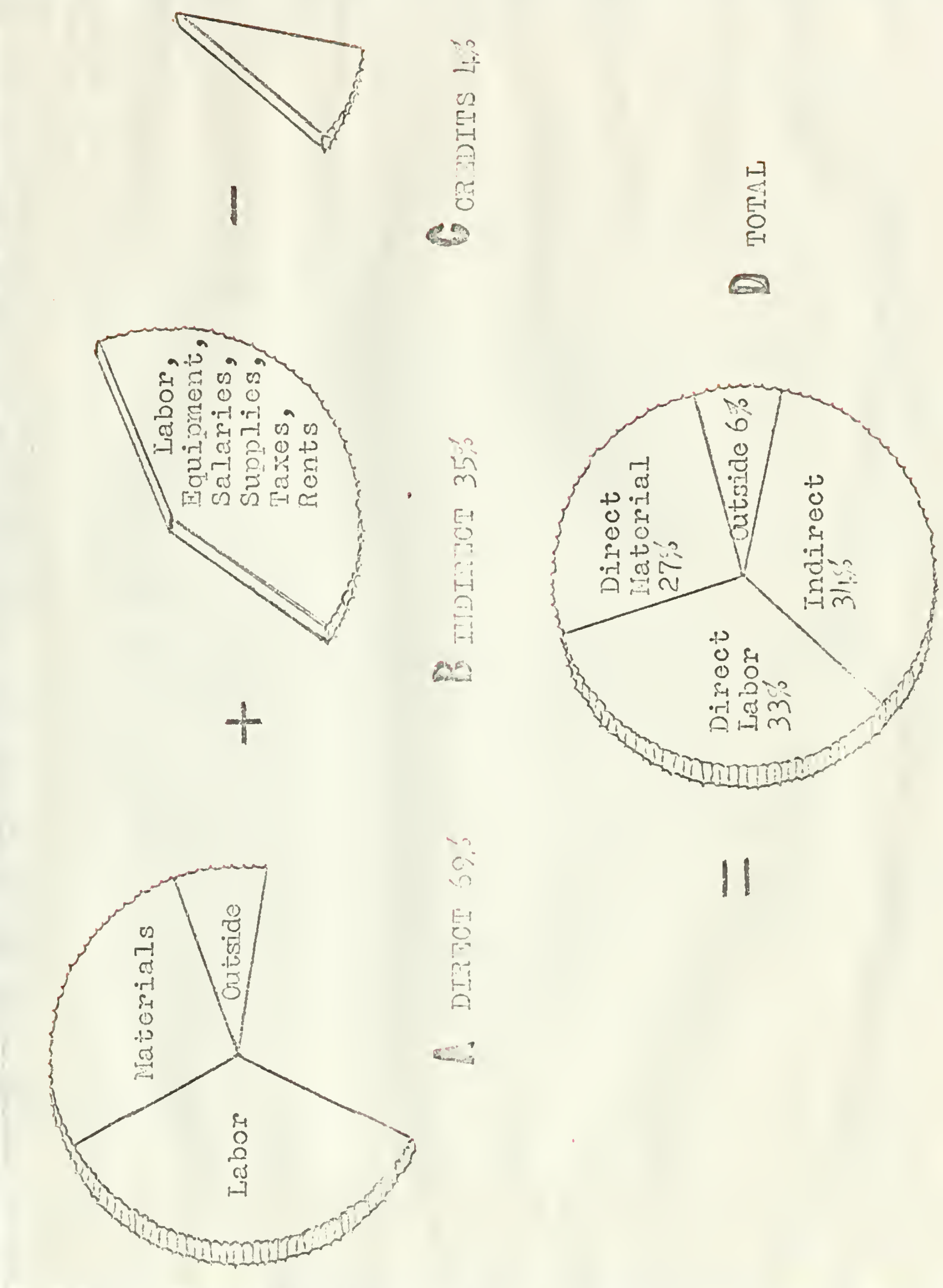

Figure 3.--General Distribution of
Airline Maintenance Expense

Source. Letter from R. M. Adams, Vice President Engineering and Maintenance, Continental Air Lines, Inc., Los Angeles, Calif., 3 Dec. 1963.

engines, and all the associated instruments, accessories, radios and equipment. These direct costs account for approximately 69 per cent of the maintenance expenses. Of these direct expenses about 50 per cent is for labor, about 40 per cent is for materials and about 10 per cent is for outside services.[1]

The percentage of direct costs accounted for by materials is constantly increasing over the years with new aircraft designs involving more and more expensive parts which are not easily repairable, or capable of being made by the airline itself.

The amount of money spent on outside services varies between airlines and within a given airline it may vary between aircraft types. It is a function of the amount of work sent to outside agencies. As such, the figure is a little impure in the direct cost sense since the billings will include labor, material, overhead and presumably the profit for the outside concern.

Indirect Costs

The remainder of the maintenance dollar is spent in indirect costs, amounting to 35 per cent as can be seen in Figure 3B. The obvious excess over 100 per cent of the expense dollar resulting from the addition of direct and

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[1] Letter from R. M. Adams, Vice President Engineering and Maintenance, Continental Air Lines, Inc., Los Angeles, Calif., 3 Dec. 1963.

indirect percentages is corrected by deducting 4 per cent for credits which are the profits from doing work for outsiders. This approach should point out to maintenance managers one way to do something about maintenance expenses, that is, perform work for others if you can do so at a profit. The adjusted direct and indirect expense dollar percentages then show on the total, Figure 3D.[1]

The greatest portion of the indirect costs are payroll related. For the sake of examination, in Figure 4 the indirect costs are broken into three arbitrary groups using labels of staff support burden, assisting burden and nonproductive burden. Now considering them in the reverse order, nonproductive burden runs about 35 per cent of the total burden and is made up of federal and state payroll taxes, company contributions to retirement and welfare funds, labor charges for holidays, sick leave, injury, vacations, cleanup, standby and so on. Assisting burden is about 34 per cent of the total burden and is primarily comprised of shop supplies, expendable materials, hardware, cleaning compounds and stationery, light, heat, power and water, rents, guards and janitors, telephone and teletypes, expendable tools, materials, labor, gas and oil to maintain and operate ground equipment. The third group, staff support burden,

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[1] Ibid.

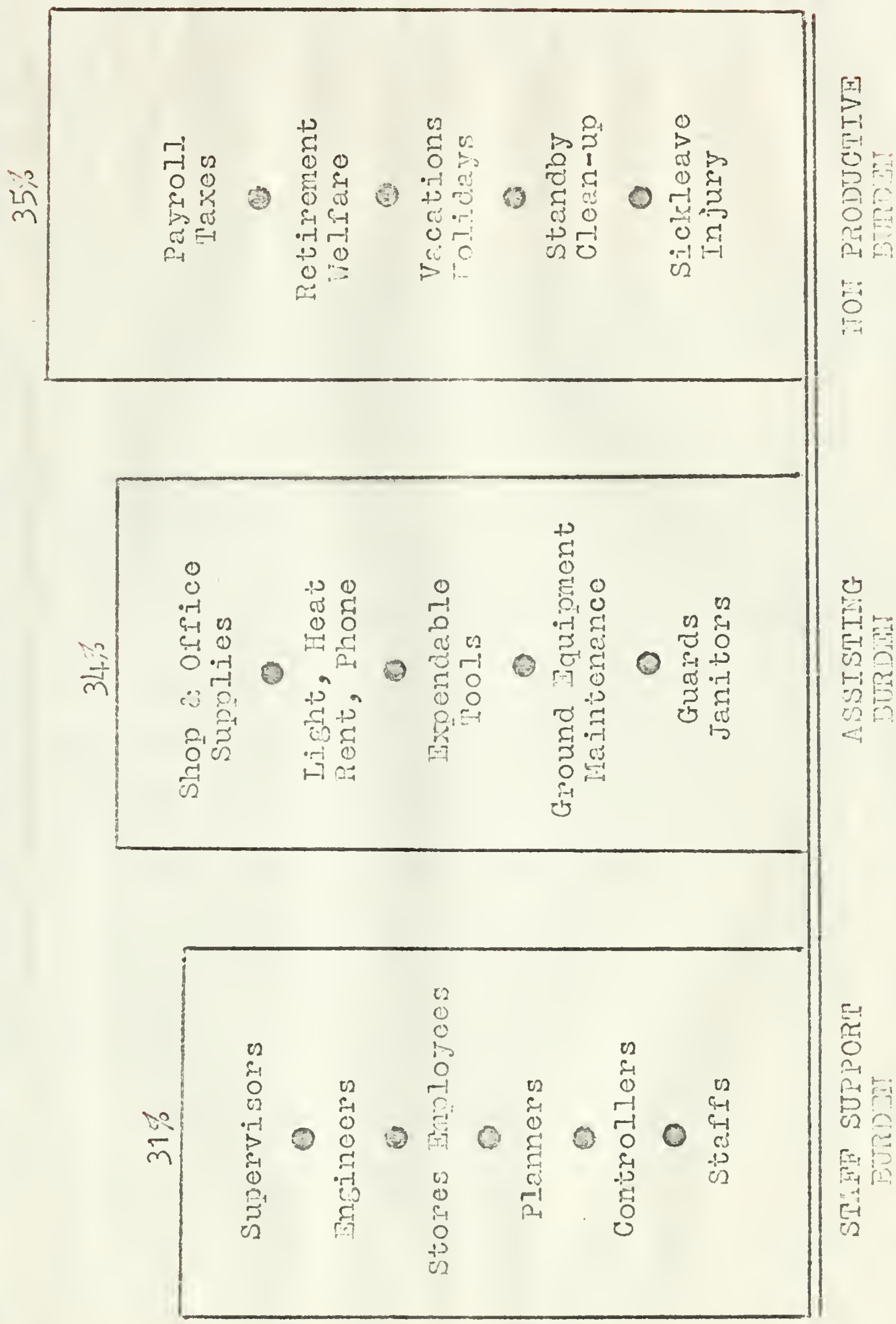

Figure 4.--Distribution of Indirect Maintenance Expense

amounts to about 31 per cent of the total burden and is made up of salaries for people in supervision, engineering, production control and planning, stores keeping, records keeping; plus training costs, travel expenses and the like.[1]

This is where airlines maintenance money goes. Now how can cybernetic systems help management to reduce costs? First, consider indirect costs.

Support Staff Burden

Little relief can be expected in this area by cybernetic systems. There will probably be a shift in the composition of these functions but the total expense will likely remain constant. The shift will probably be from middle managers toward top managers. The overall number of people will be drastically cut but the cost per employee will probably rise sharply. For example, the need for certain staffs, accountants, store employees and supervisors will drop sharply with the advent of cybernetic systems but the need for engineers, planners and top level managers will rise.

The percentage of indirect to direct cost is not the important factor; however, the overall cost is. If the burden costs stay constant and productivity increases,

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[1] *Ibid.*

the total dollars of burden will increase, yet direct cost may decrease sufficiently to have a substantial overall decrease in unit costs. The staff support dollar should, then, more than pay its way with cybernetic systems.

Nonproductive Burden

Returning to Figure 4, consider the nonproductive burden. It is in this area that the greatest savings can be effected. Cybernetic systems can reduce the overall need for workers as the writer attempts to point out in material developed in subsequent chapters. The impact of savings in this area is more graphic if one considers that 18 per cent of each worker's total cost is paid directly into unproductive cost -- taxes and fringe benefits.[1] One should consider also the social trends of the day and that state and federal law falls outside of most maintenance management's direct influence.

Assisting Burden

Obviously there will be no savings in this area. With the introduction of cybernetic systems there will be a sharp rise in costs in this area for rent or purchase and installation of sophisticated equipment. The cost increase in this area will offset any savings realized in

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[1] *Ibid.*

the nonproductive area. Increased productivity, however, will be the key consideration (as discussed previously).

Reducing Costs

One of the major avenues for reducing direct labor and materials costs lies in the introduction of cybernetic techniques and philosophies. These improved maintenance systems and techniques will permit accomplishment of maintenance only when it needs to be done and will get the job done in the most expeditious manner.

It will improve scheduling to assure that the job is not performed before that time arrives and will see that this time arrives in a smoothly patterned workflow. These statements are elaborated on briefly in reverse order.

Scheduling

Flight schedules are primarily set to produce revenue by flying where and when the customer wants to. Minor changes in these schedules can have a large bearing on maintenance manpower requirements. A very simple example is a line station with five transit flights occurring in one shift, as shown in Figure 5. By having the flight transits scheduled end to end, only one ground crew is needed. By superimposing only two of the transits, two ground crews are needed, and they produce

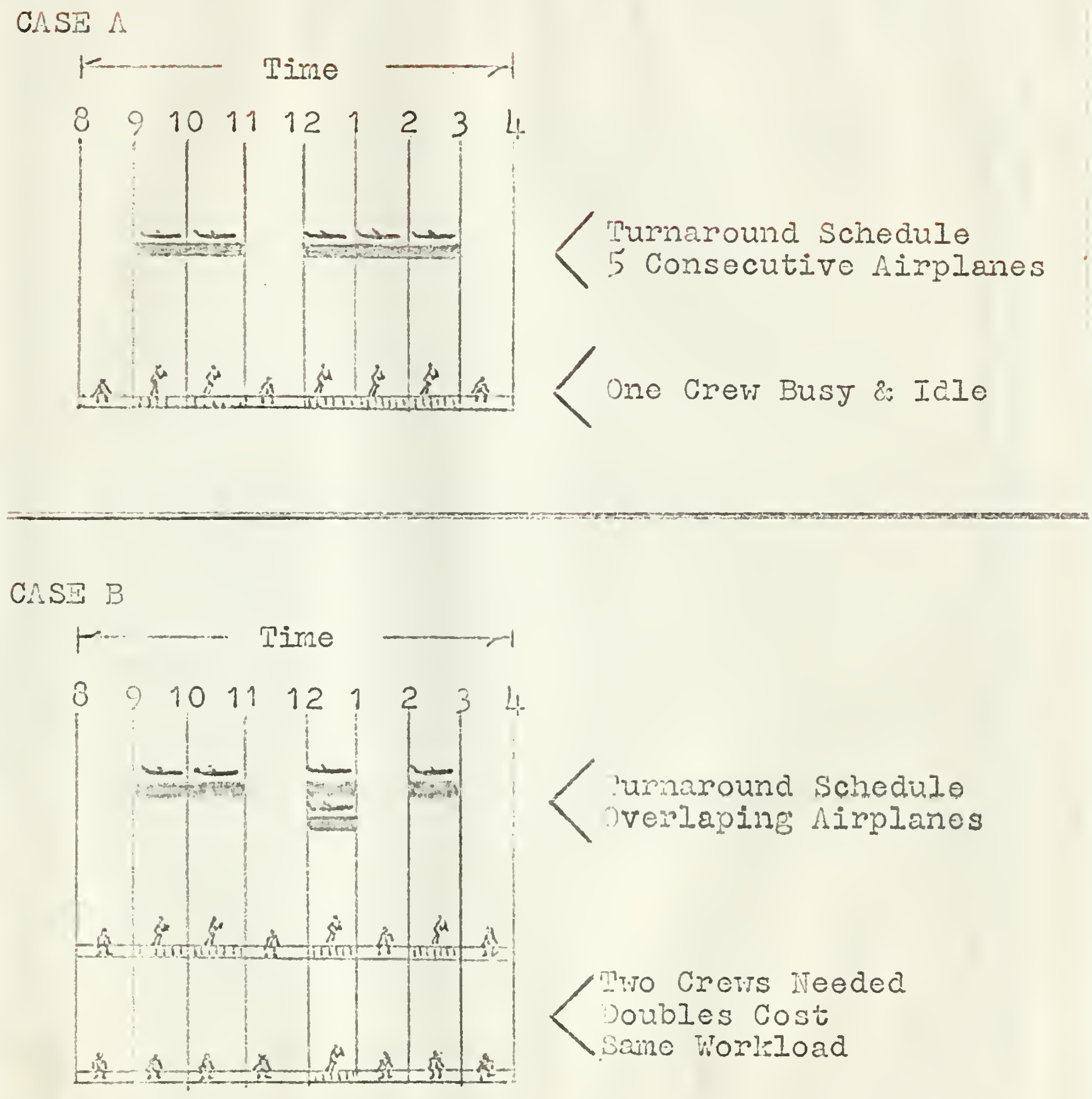

Figure 5.--Scheduling Effects on Cost,
Example 1

no more than did one crew, but with a 100 per cent increase in cost. Cybernetic management techniques can assimulate this problem -- compounded by passenger demands setting the basic schedule, 150 plane fleets, thousands of time-controlled parts -- and come up with the best schedule.

Another area in scheduling that could result in direct cost savings by computer assimulation is illustrated in Figure 6. Assume a time limit of 100 hours between the recurrent performance of some task which uses $100 worth of labor. If for some reason scheduling results in this job being done at 80 hour intervals, and improved scheduling increases the interval to 96 hours, a cost reduction is achieved from $1.25 per flight hour to $1.04 per flight hour -- a decrease of nearly 17 per cent. Now suppose that they found out that they really didn't need to perform this job at 100 hour intervals, but that it would go for 300 hours safely, with a cost increase for added wear to $120. The cost per hour would then be only $0.42 per hour or more than a two-thirds reduction from our starting figure of $1.25 per hour. This type of major cost improvement is possible through use of cybernetics.

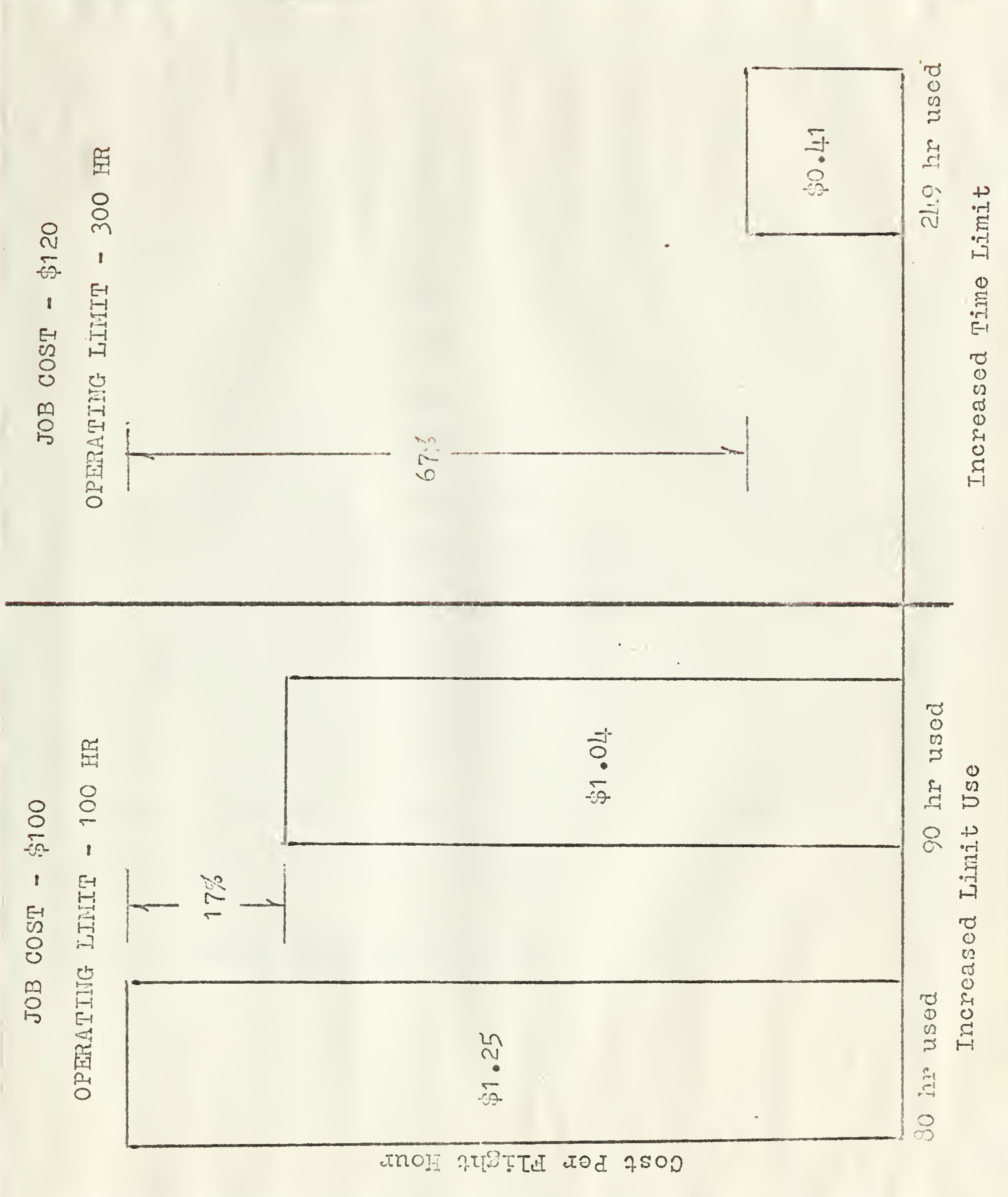

Figure 6.--Scheduling Effects on Cost,
Example 2

Improved Techniques

First of all, when an airplane is undergoing maintenance work it isn't earning revenue. It is simple arithmetic that any technique to improve and speed-up overhaul periods will effect large reductions in cost. If overhaul periods are cut from 5 days to 4 days, there is, of course, a one-fifth savings in overhaul costs and the aircraft is out earning revenue on the fifth day.

It should be just as obvious that maintenance management needs the development of systems that monitor the condition of all the components and aircraft structure without requiring expensive disassembly of the aircraft with all of its bad side effects of Murphy's Law[1], mechanic tinkeritis and other built-in costs.

It is in the area of direct costs -- where costs are ever increasing because of technological improvements -- that cybernetic systems will effect the most in savings for aircraft maintenance managers.

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[1]Murphy's Law. If an aircraft part can be installed wrong, someone will do it.

CHAPTER III

COMPUTER CONTROL -- AN AID TO AIRLINE MAINTENANCE

Airlines in the United States began to entrust more and more engineering and maintenance functions to computers in the late 1950's in an effort to reduce the $670 million they spend each year on maintaining and overhauling aircraft.[1] The maintenance of aircraft presents unique problems since failure while a plane is in the air can cost human lives and entail millions of dollars in equipment loss and passenger suits. The latest technique for maintaining flying equipment in peak operating condition is computer control of accumulated time on airframes, engines and time-controlled parts -- the preventive maintenance concept.

Preventive Maintenance Scheduling

Preventive maintenance is a comparatively new concept that calls for the progressive overhaul of certain critical parts of a unit at specified time intervals. If statistical data show that hydraulic pump bearings on certain aircraft fail after 1,000 hours of flight, this

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[1] Damm, loc. cit.

item must be marked for removal at 1,000 hour intervals. Such a system of controlled maintenance, therefore, safeguards against breakdown. Hours flown, then, has been established as the measuring stick for routing aircraft to overhaul stations.

The job of scheduling and maintenance control is the responsibility of the airline engineering and maintenance department. Volumes of records are kept to control huge stocks of items, determine component failure rates and schedule and maintain equipment over a large network of operations. At least 60 per cent of an airline's total manpower may be assigned to this area, ranging from dispatches, central overhaul crews, station maintenance crews, and an engineering staff to office control clerks, general supply clerks and parts warehousemen.[1] Because of this, maintenance managers have been struggling to accomplish some streamlining of records. The problem is complicated, however, because their staff must be in immediate possession of the following essential data:

a. What units are scheduled for the next overhaul period?

b. What components are due for the next overhaul?

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[1]American Airlines, "Tulsa Management Research Application No. 5001, SPQ Computation/RL Control," Tulsa, Okla. (Mimeographed.)

c. What are the presently installed components?

d. What are the prematurely removed components?

e. What are the failure rates for each component?

f. What components are on hand at the overhaul base and at each terminal station?

The airlines maintenance and engineering departments maintain four types of records that furnish all the necessary information to answer these questions:

1. Master Unit Record. Data is maintained by unit serial number showing hours flown since last inspection or overhaul; date since last inspection or overhaul; and other miscellaneous historical information.

2. Component Overhaul Record. Records are filed by part-number sequence by unit-serial number. Data includes date component was installed, and hours since last inspection or overhaul.

3. Parts Stock Control Record. These records contain information required to control each of the component items stocked at the various outlying maintenance activities and the central maintenance location.

4. Component Performance and Irregularities Record. Irregular removals and scheduled removals are recorded throughout the month. Summary calculations are made at month's end for plotting to analyses curves. This aids management in deciding through actual performance if

the overhaul period for that item might now be extended. The result is less shop repair and lower maintenance costs. On the other hand, numerous failures over a period of time may cause shorter overhaul periods. This entails additional shop repair.[1]

Prior to the adoption of the computer, most airlines used a system of manual posting to ledger cards, the same system adopted with the inauguration of the preventive maintenance plan. The upkeep of groups of records was divided among several departments. American Airlines master unit records were filed in the Operations Department; component overhaul records were kept in the Maintenance Department; stock control ledger cards could be found in the Supply Department; and performance and irregularities records in the Engineering Department. Each of these departments required a separate staff of clerks.[2] Other airlines employ similar systems.

The Computer

The computer offered the first real solution to the maintenance manager's records and control problems.

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[1]American Airlines, "Tulsa Management Research Application No. 508, Workload Mechanized Production Control," Tulsa, Okla. (Mimeographed.)

[2]Letter from G. E. Darr, Manager, Systems Management Research Division, American Airlines, Maintenance & Engineering Center, Tulsa, Okla., 30 Jan. 1964.

Its concept of in-line processing meant that a single transaction affecting a component part could be posted to three individual record areas. Of equal importance was the ability of the computer to make certain decisions regarding unit scheduling and stock ordering.

With the computer a better job could be done in scheduling equipment for maintenance checks and overhaul. Component check sheets can be furnished prior to the arrival of an airplane at the terminal so that items that have not reached their overhaul period will be omitted. United Air Lines' Manager of Accounting, K. S. Hankland, stated that keeping track of low-time items could mean a half-million dollar reduction in their maintenance repair costs alone.[1] Heretofore, the difficulties of maintaining schedules on all items necessitated overhauling every component on that unit when it arrived at the main base.

With the computer it is possible to control a centralized stock inventory system for the fast moving critical components carried at both the main overhaul base and the maintenance terminal stations. Thus, emergency stock required for use at the main depot can be quickly located at any of the other bases.

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[1]Letter from K. S. Hankland, Manager of Accounting, United Air Lines, San Francisco, Calif., 16 Dec. 1963.

Furthermore, because this stock can be closely controlled, the amount of inventory carried in the stock bins can be substantially reduced.

General Airline Application

Transcontinental airlines operate average fleets of 150 aircraft. Because each plane is made up of 500 maintainable parts, individual records for 75,000 component items might be kept on file. The computer is used to control the in-service time by scheduling the 150 aircraft through three basic types of maintenance checks:

1. Enroute check, for aircraft logging less than 125 hours flight time.

2. Intermediate line check, performed every 125 hours.

3. Overhaul check, at each 2,000 hours on components and airframe. (A total of 8 of these 2,000-hour checks might constitute a complete overhaul cycle.)[1] (See Figure 7).

In addition, all 500 components of each of 150 aircraft are time-controlled and their stock records updated. Summary failure data or irregularities are

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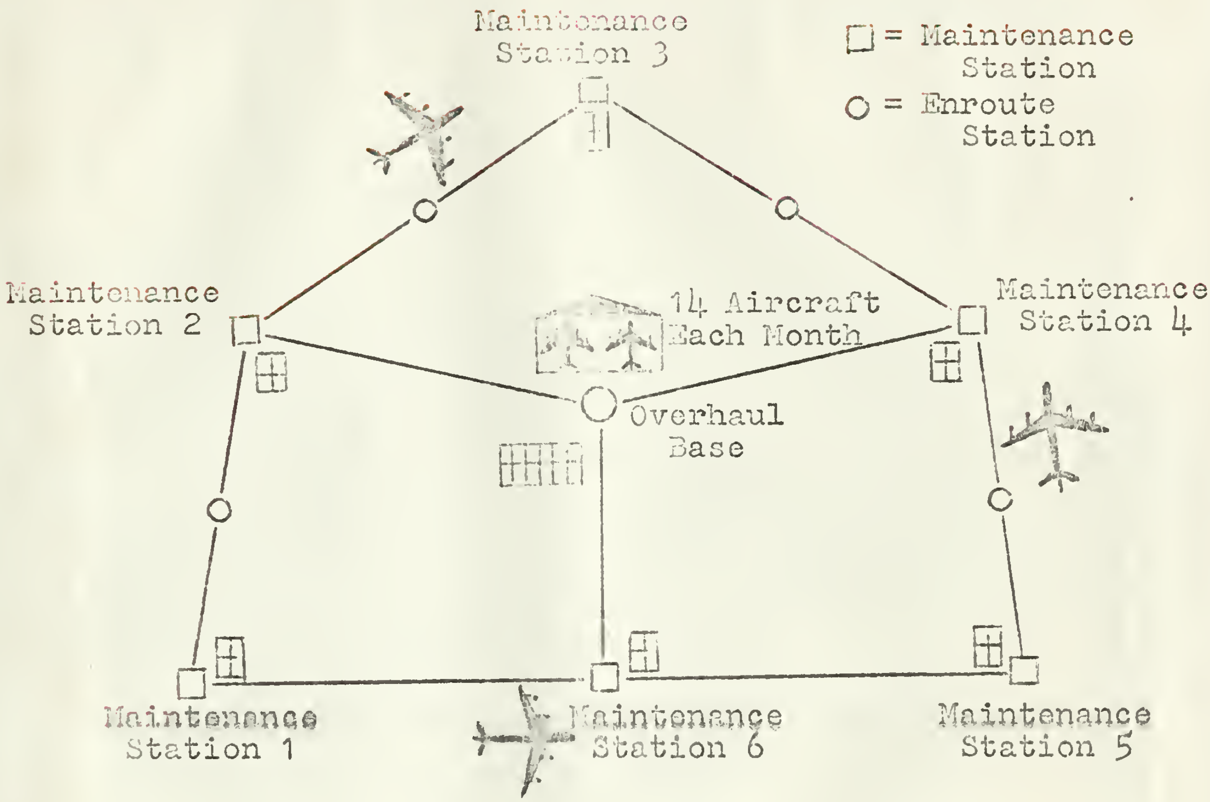
[1]Norberg, J. W., "Organizing & Managing For The Maintenance Job," IATA Production & Control Group Paper for Ninth Meeting, Hamburg, Germany, 10-14 June 1963. (Mimeographed.)



Type Maintenance	Frequency	Location
Enroute Check	To 125 hours	All Stations
Maintenance Check	125 hours	Maintenance Stations and overhaul base
Preventive Maintenance overhaul	2,000 hours	Overhaul Base

Figure 7.--System of Airline Maintenance Stations

also recorded so that the performance of every one of the items may be analyzed within its overhaul period.

The input data fed to the computer consists of only four types of data:[1]

1. Flight Leg Card.

2. Serviceable Part Tag.

3. Repairable Part Tag.

4. Miscellaneous Inventory Card (i.e., receipts, adjustments, etc.).

A flight leg card is a teletyped message from a terminal setting forth a plane's hours flown between two points. Supplementary data might well be included, such as ton-mile traffic, crew numbers, etc. This information is then fed daily into the computer to update flight times on the 150 aircraft master disk records.

A serviceable part tag is an item carried in the stock bins which is requisitioned by the mechanic for installation on an airplane. A repairable part, on the other hand, is an installed item that has been removed from the aircraft because of faulty condition and must now be routed to the shop for repair. These tags alter both component overhaul and stock control disk records, and in some instances might also be recorded on the component performance disks.

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[1] Ibid.

Scheduling decisions now become automatic. For example, the in-line printer will print each plane's date due for overhaul by calculating current time since overhaul plus anticipated future flying time. It will also print maintenance check sheets, itemizing only those component items due for removal at a particular period.

The organization of the computer file is generally simple. Aircraft records, for example, can be stored on a portion of one disk face of a computer disk storage unit; the 500 stock control records and 500 component records appear on one disk each; and the 75,000 component overhaul records can be packed into the remaining disks.[1]

Input volume in the system described is exceptionally low for a computerized system -- a top average of perhaps 25,000 cards per day.[2] Utilization is usually made of any remaining unused disk file to accommodate storage of technical data.

A Technical Library

Storing engineering and technical data on computers for various complex aircraft systems is another recent innovation. Volumes of books, reams of specifications and thousands of blueprints, drawings and diagrams are used

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[1] Ibid.

[2] Ibid.

by the maintenance manager to maintain and service an aircraft. Finding the right information for a job frequently involves hours of search.

Figure 8 shows a schematic example of the Boeing 727 and electronic data processing of its electrical wiring data. Basic wiring data from engineering and manufacturing is stored in the computer on magnetic tape. The computer is then programmed to provide information useful to maintenance. The principle benefits of this program stem from the speed and accuracy at which all the interrelated wiring data is made available to those affected. The simple logic of the computer forms a more complete engineering definition of all wiring details than was normally available. For example, each ground and splice in an aircraft electrical system is now completely identified and its location specified.[1]

The overall benefit to the maintenance manager is that more complete system data is now available quickly and more easily than by the former manual methods.

The scheduling of equipment and its components for inspection and overhaul is a new application for computers.

Major U.S. airlines, however, now have a comprehensive computer controlled accounting system, as

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[1]The Boeing Company, Airplane Division, "727 Wiring," Renton, Washington, 1963, pp. 68-72.

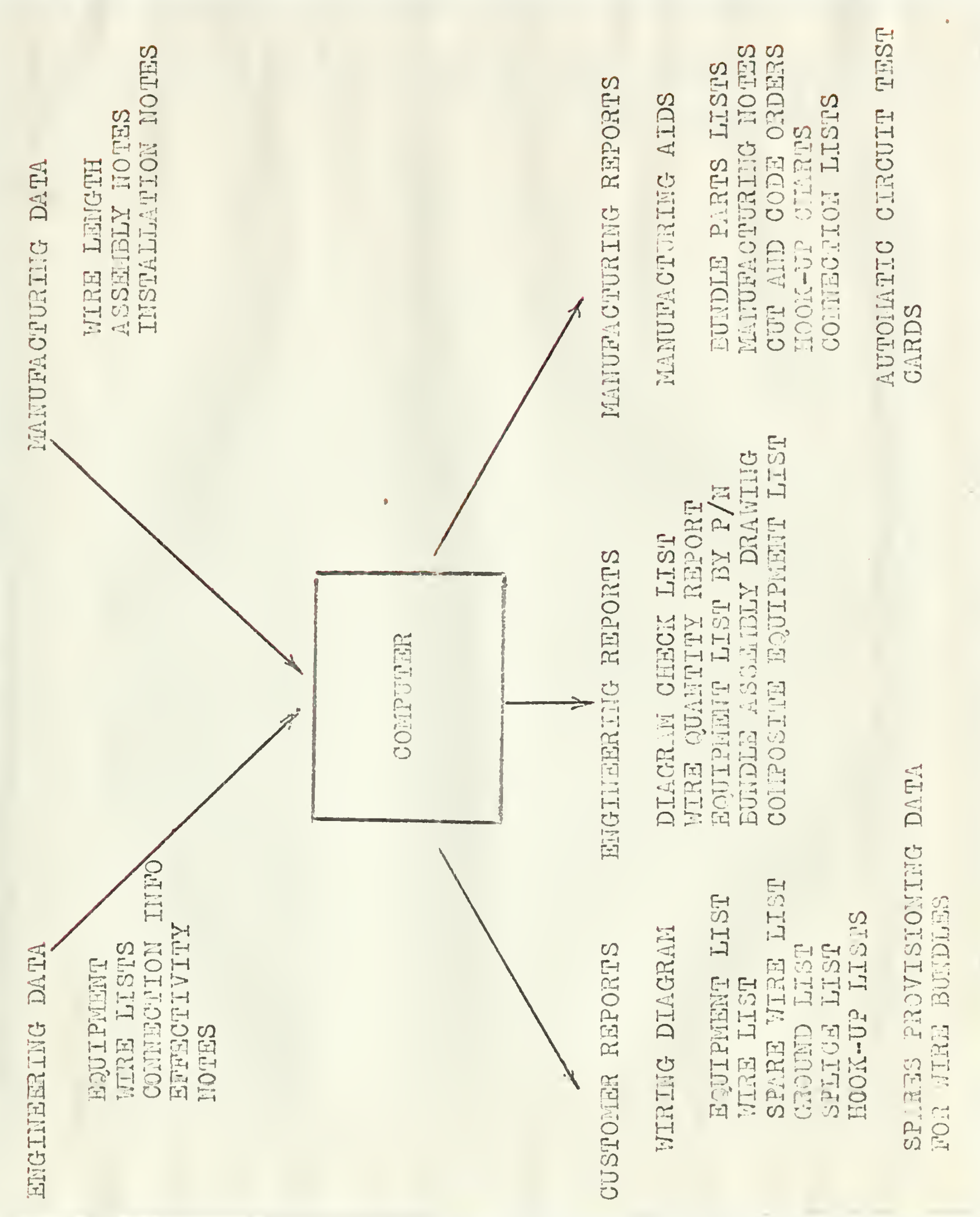

Figure 8.--Schematic of Electronic Data Processing of Electrical Data on Boeing 727

Source. The Boeing Company, Airplane Division, "727 Wiring," Renton, Washington, 1963, p. 69.

described, as part of their system of scheduling equipment and its components for inspections and overhaul. The next chapter describes Trans World Airlines' specific application of this technique.

CHAPTER IV

TRANS WORLD AIRLINES' COMPUTER SYSTEM

Trans World Airlines has installed a contralized maintenance system at Mid-Continent Airport near Kansas City with a communications and data processing link to 73 cities in the United States and 23 bases elsewhere along the airlines' 50,000 route miles.[1]

This international carrier spends nearly $90 million annually on maintenance. The system inaugurated in January 1961, features a Royal Precision LGP-30 computer which is used in conjunction with a world-wide teletype system. Daily reports received by wire from bases in other countries can be analyzed by the computer in minutes and the results teletyped back.[2]

A major segment of Trans World Airlines' maintenance program involves keeping tabs on more than 25,000 power plant parts and 50,000 airplane parts

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[1]Trans World Airlines, "Data Processing Engineering Applications," Kansas City, Mo., 13 Jan. 1961. (Mimeographed.)

[2]*Ibid.*

designated as time-controlled units. Subject to strict control by Federal Aviation Authority, these units must be replaced periodically as use-time mounts.[1]

Under TWA's integrated system the computer keeps track of the hours accumulated by each unit under control. The Royal McBee computer is desk sized, yet it has sufficient capacity to monitor more than 6000 different units used on 184 aircraft.[2]

Each morning the LGP-30 is fed information on every aircraft in the fleet. Previously this information took days to arrive from distant bases. The tele-type-computer combination provides current, comprehensive reports which formerly were impossible.

The Computer Program

The LGP-30 is a low-cost, high memory computer with a simple command structure of 16 commands such as "add," "subtract," "multiply," and "divide." It has space for 4096 words in its memory. It is located in the maintenance administration office rather than in a centralized data processing group. TWA personnel spent two weeks at Royal McBee's computer course to learn the unit's operation.[3]

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[1] Ibid.

[2] Ibid.

[3] Ibid.

TWA says the computer:

1. Speeds accumulated-hours reports. Daily rather than bi-weekly reports on time-controlled unit changes coming due are now available. Unit time since overhaul is computed and printed automatically as changes are fed in.

2. Facilitates aircraft scheduling. Lead time needed to schedule engine and other unit changes has been reduced as much as 50 per cent.

3. Facilitates shop scheduling. Accurate computer forecasts of future work assists in planning the shop workload.

4. Maximizes utilization of time-controlled parts. Time-controlled parts are now being run nearer to their allowed limits due to the daily updating of the aircraft files.

5. Forecasts maintenance-due dates. Such forecasts for power plants and other components are prepared in a fraction of the time previously required.

6. Increased data processing capacity. The volume of time-controlled unit activity is increased approximately 50 per cent by the addition of jet fleets. Aided by the computer, this additional workload is being handled with present personnel.

7. Updates part history cards. Part history cards for more than 30,000 time-controlled parts are posted in half the time through the use of computer reports.[1]

The Power Plant

Computer Programs at TWA can be divided into three major parts. The power plant program, the first to go on time, rides herd on more than 800 piston units, plus 6 to 10 time-controlled parts per piston engine and 15 units per jet engine.[2]

Time-controlled power plant parts are short-hour units whose service life falls far short of the airframe overhaul times of 4000 hours for piston aircraft and 3000 hours for jets. Jet engines must be removed and inspected at least once during each overhaul cycle. Piston engines are pulled after 1500 to 2200 hours of service for overhaul. Time-controlled parts include propellers, power recovery turbines, turbo compressors, jet fuel controls and others.[3]

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[1] Nickerson, D. H., "Project Report TWA," Kansas City, Mo., May 1961. (Mimeographed.)

[2] Trans World Airlines, loc. cit.

[3] Nickerson, loc. cit.

Stored in the computer's memory are plane numbers, engine numbers and locations, time-controlled unit serial numbers and the time since last overhaul for all items, plus basic program information on FAA-allowed time limits. Each morning, the previous day's flight hours for every aircraft are received, punched into tape and fed into the computer.

Input is plane number and flight hours. The computer finds the right plane listing and updates all items. It then checks certain specified parts against FAA maximum time limits and prints out the time the part change must be made and remaining hours. Part removals are read into the computer daily.

Since TWA divides its aircraft into fleets based on plane types, all computer programs are run by fleets. The basic information on maximum time limits and parts stored in the computer varies by plane, necessitating this common-plane approach.

Updating power plant time-controlled units, searching for unit changes and punching out a new master file takes about 90 seconds per plane. The largest of the nine fleets -- twenty-eight planes -- is processed in fewer than 45 minutes.[1]

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[1] Trans World Airlines, loc. cit.

Time-controlled parts that have exhausted their allowed time are returned to the Kansas City Maintenance Base for complete overhaul. Unit time reverts to zero hours. Parts that are removed because of a malfunction are sometimes repaired and continue to accrue time in service until reaching the FAA specified maximum.

Approximately 6000 different units are repaired in TWA shops. The production rate of these units is 430 per day. About 100 piston engines are overhauled each month. The jet engine overhaul is presently 65 overhauls per month.[1]

The Airframe Program

Time on the airframe itself and associated airframe parts such as cockpit instruments, landing gear and automatic pilots is also controlled by the computer. Tabulating time on the airframe is straightforward accounting. Controlling time on airframe parts is similar only in some respects to controlling time on power plant parts.

Unlike power plant parts, airframe components are long-hour units whose useful life generally exceeds the airframe overhaul period of 3000 to 4000 hours. Previously these parts -- numbering about 80 for piston

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[1] Nickerson, loc. cit.

craft and 130 for jet -- were updated only when the plane arrived for overhaul.[1]

By putting the airframe program on the computer, an accumulated hours report is available daily. Given this information, it is now economically possible to run parts nearer to their allowed limits, changing them between base overhauls during regularly scheduled checks.

Once parts have been removed, part history cards must be brought up to date. By printing out complete information on parts removals the computer has helped halve the posting time.

The plane file tape containing complete information on the plane and parts is not stored in the memory but is run through the computer one plane at a time. The computer upgrades time and makes all pertinent part changes. It notes whether or not newly installed parts will reach the next airframe overhaul without exceeding specified overhaul limits and points out exceptions with the aircraft time at which the units must be removed.

Alterations to the master file are then printed out for use with the next day's updated run. The complete updating transaction requires fewer than two minutes per

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[1] Ibid.

plane on the average. Error checks throughout the program guarantee accuracy.

Unit Change Simulation Program

As an aid to scheduling and planning, TWA has built a unit change simulation program now used only for complete power plants which presents a 30-day forecast of engines that will come due for inspection and overhaul. Based on assumed conditions proven by past experience, the program print-out is an itemized list of engines and maintenance-due dates.[1]

Mr. Nickerson, TWA's Director of Data Systems and Design, says, "Current computer programs represent only a segment of the workload planned for the future."[2] Since the time-controlled part program has produced savings in maintenance costs through maximum utilization of part life, it will be expanded to include additional parts.

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[1] *Ibid.*

[2] Letter from D. H. Nickerson, Director of Data Systems and Design, Trans World Airlines, Kansas City, Mo., 29 Dec. 1963.

CHAPTER V

UNITED AIR LINES DEVELOPS COMPUTER TECHNIQUES FOR OVERHAUL

A new management technique called "critical path analysis" has been developed to speed aircraft through overhaul at United Air Lines, San Francisco Maintenance Base. This planning and production control tool, adapted from the PERT[1] system of military and space management programs, is made possible by computers such as the IBM 1401 and their ability to assimulate vast quantities of raw data.

Management Problem

United's Overhaul Base must provide safe, dependable aircraft on time for airline service. Safe in terms of flight quality standards and FAA requirements, dependable in terms of airline schedule performance with a minimum of delays to the passenger, and on time in terms

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[1] PERT -- The Program Evaluation and Review Technique is one of the newest and most promising of the computerized management planning and control devices. It is a tool which is used for defining, integrating and interrelating what must be done to accomplish program objectives on time. Its three salient features are planning, scheduling and the concept of the critical-path.

of minimum out-of-service time for the maintenance and overhaul activity. The commercial turbo-jet airliner costs $6 million and United calculates when grounded for repairs it costs $3,000 of potential revenue each hour it might otherwise be in the air.[1]

The specific goal at United's Overhaul Base was to completely overhaul a very complex aircraft such as the DC-8 or B-720 in five days. This involved planning and scheduling 12,000 man-hours and some 2,000 different jobs (of which only about 50 per cent are known beforehand) within an elapsed time of 120 hours, and not just once, but routinely each week through the year.[2] This, then, is the specific problem United attacked and this chapter will describe their approach and final solution adapted from the PERT technique.

Turbo-jet Airliner

United's Base Overhaul had been using traditional planning and scheduling tools for years, such as Gantt or bar charts, sched-u-graph, etc. However, when the turbine aircraft were introduced, they found these systems could not cope with the magnitude of the problem.

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[1] The Wall Street Journal, 11 Feb. 1964, p. 1.

[2] Letter from P. A. Wood, Vice President Base Maintenance, United Air Lines, San Francisco Base Maintenance, 11 Dec. 1963.

These planning systems had deficiences resulting from techniques which were inadequate for dealing with the complex job of overhauling a large jet aircraft.

The volume of paper, the coordination required in sequencing work among seven key crews, timing of part requirements and communicating work accomplishment through three shifts, simply overwhelmed the planning center people.[1]

Critical Path Analysis

PERT (critical path analysis) is used for project type activities such as heavy contruction, facilities' maintenance, shipbuilding, and research and development of military programs. United Air Lines found that the factors common to these typical projects were also common to the overhaul of a turbine aircraft; namely, the end products of the operation are few in number; the operation is composed of a large number of serial and parallel jobs; all of these jobs are directed toward a common objective; there is a degree of uncertainty in the production method, time required and allocation of resources; and several

[1] Ibid.

organizations are involved, having different jobs to be done and having communication problems.[1]

To draw a parallel, major maintenance or overhaul of aircraft combines a thorough inspection, scheduled changes of many components and any modifications required on the airframe or aircraft systems. The pattern of this type of maintenance is disassembly, inspection, repair and or modification as required, reassembly, then operational check. This is a rather straightforward concept and in the case of piston aircraft, United had years of experience and relatively simple systems to contend with. This made conventional planning and scheduling systems quite capable of handling the situation. With the appearance of very expensive jet aircraft and the pressure for high utilization of the equipment, the picture changed.[2]

The attempt will not be made here to describe the technique of critical path (PERT) since a great deal of literature is available on the subject.[3] Essentially, the

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[1]United Air Lines, "Project 34 Turbine Aircraft Overhauling Scheduling System," San Francisco, Calif., 20 Sept. 1960. (Mimeographed.)

[2]Wood, loc. cit.

[3]For a description of this technique see: White, Glenn L., "Computerized Project Network Analysis," The Military Engineer, Vol. 55, No. 366, July-August 1963, pp. 236-239.

critical path analysis provided United with the means to diagram the interrelationships among various jobs, identify the skill and manpower required for each operation and finally come up with the proper sequencing for completion of the total overhaul in the shortest elapsed time. "In a way," says Percy Wood, head of United Air Lines Base Maintenance Department, "critical path analysis applies the same common sense to a production problem that the human brain would if it could stretch that far and assimulate all the facts."[1] Initial efforts to develop critical path charts amounted to a trial and error method. Eventually it boiled down to the construction of eight network charts which comprised the eight key maintenance areas of the airplane. These were hydraulic system and control surface rigging, cabin, radio and electrical system engines, air conditioning, fuel and the cockpit. Conventional arrows were used to represent individual jobs in these networks. Certain innovations were necessary. For example, the independent treatment of the networks representing the eight area groupings was not completely realistic. In some cases an operation in one category was a prerequisite to another represented in a different network.[2] This had

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[1]Wood, 9 Dec. 1963, loc. cit.

[2]United Air Lines, Project 34, loc. cit.

to be shown where its effect was felt -- outside its parent grouping. In other cases there was little or no reason to show one job ahead of another. An arbitrary sequencing was established.[1]

The network was laid out in general terms, based on observation and analysis. Then it was progressively refined through consultation with experienced foremen and highly skilled maintenance personnel. These diagrams, then, comprised the master plan for the overhaul and permitted visualization of the entire process. This, incidentally, was one of the first major benefits obtained from the effort.[2] It proved to be an excellent communication device for discussing the method and management of the overhaul process. In the method area, for example, a number of inadequacies and errors in the job card operation were turned up and many changes were necessary in order to properly organize the individual jobs.[3]

The Computer

Upon completion of the network development a computer program was prepared for the IBM 1401. This

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[1] Ibid.

[2] Ibid.

[3] Ibid.

program provided the means for identifying the critical path. In addition, several print-out variations were added to provide the foreman with a simple control tool. For example, the standard critical path print-out for the total overhaul would be too cumbersome for a foreman to work with, therefore the information was sorted out for each of the key networks and assembled in order of increasing slack. In other words, critical jobs with no slack at the top of the page followed by the near critical jobs, and so on.[1]

An initial trial period of six months was set up to test and "debug" this method of scheduling in real life. The eight network diagrams were posted in the work area so that maintenance personnel could become familiar with the method of representation and thus be in a position to contribute refinements. In addition, a twice daily computer run was prepared. It enabled management to see delay situations developing and take the right action to avoid or at least minimize the consequences.[2]

United rated the test successful with a definite improvement in moving toward a scheduled five-day overhaul. The foreman became highly conscious of the

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[1] Ibid.

[2] United Air Lines, "Project 83 -- Turbine Aircraft Overhaul Scheduling System -- Status Report," San Francisco, Calif., 13 Nov. 1962. (Mimeographed.)

critical path jobs. He was in a much better position to allocate job priority and skills, and he based his decisions on realistic criteria -- especially those on-the-spot decisions that always occur.[1]

As far as further development of critical path was concerned, the test demonstrated that invariably the governing network proved to be the hydraulics system and flight control rigging. These were the controlling factors leading to on-time versus late release. As a result increased attention was focused on hydraulics and rigging and the other networks were de-emphasized.

Today this modified critical path system is installed and operating at United Air Lines Base Overhaul.

Results

The application of this technique to the scheduling problem of overhauling turbine aircraft and engines has produced the following results:

1. It has resulted in improved descriptions of the detailed work with an overhaul and this in turn has permitted better analysis and coordination by management.

2. It has afforded effective centralized control over the various phases of the overhaul.

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[1] Ibid.

3. It has provided well-founded sensible sequencing of the many and varied jobs to be done in the highly complex and specialized aircraft systems.

4. It has permitted better parts availability. More realistic predictions of need-times lessened the amount of expediting necessary and resulted in smoother flow of components among the support shops, stock rooms and overhaul docks.

5. It has reduced out-of-service time of the aircraft being overhauled.[1]

Critical path analysis, a planning and production control technique, is made possible by the computer. This method doesn't decrease the amount of work that needs to be done. But it does help get tasks better organized and in getting jobs assigned and accomplished in a more orderly and efficient manner.

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[1] Ibid.

CHAPTER VI

AUTOMATIC CHECKOUT EQUIPMENT

Previous chapters have shown airplanes are expensive machines to keep idle. Implicit in any cost consideration, of course, is the problem of personnel required to accomplish maintenance activities. As the airplanes and the equipment installed on them become more and more complex, it becomes more and more challenging for maintenance managers to find ways and means of deploying mechanical personnel to accomplish most efficiently the job at hand. It appears there is a trend toward increasing specialization of mechanical personnel and, of course, higher labor costs. One hope that might make this trend unnecessary is in the increasingly effective use of automatic checkout equipment, which would make a generally good mechanic effective in trouble-shooting systems whose innermost secreta he might not fully understand.

Types of Maintenance

Generally speaking, an airline accomplishes maintenance on its flight equipment on a two level plan.

Routine maintenance of a "day-to-day" nature commonly called line maintenance is accomplished usually at several stations situated along the airline route. Such maintenance ranges from routine handling of flight crews to relatively complete preventive maintenance checks (discussed in prior chapters) that take up to 24 hours and many hundreds of man-hours to accomplish, these being done at intervals of 100-200 hours of flight time. At greater intervals, roughly in the 2000-4000 flying hour range, the airplane is brought into a central maintenance facility where it is laid up for a period of approximately a week during which time it is overhauled. During this overhaul period many of the more complex units are removed from the airframe and are worked on in nearby shops where greater efficiencies can be achieved in the performance of routine checkout of the units to assure their capability of continuing to do the task assigned.

Two distinct types of checkout equipment are now utilized to service these two types of maintenance activities. The line maintenance function is served by semi-automatic checkout equipment that is considered relatively coarse in nature and whose purpose goes no further than to point out the faulty unit or "black box" that is rendering a given system unusable. In the airplane overhaul function, more elaborate and more complete checkout equipment is employed to delve deeper

into systems installed in the aircraft and in shop areas, to accomplish long and arduous step-by-step checking of complex pieces of equipment either prior to or following overhaul in a shop.

Both military aviation and commercial airlines have recognized the need for automatic checkout equipment to perform maintenance checks on aircraft systems. Application of semi-automatic checkout equipment has found wide use in radar systems, electrical systems, weapons systems and various other electronic and hydraulic systems.

Look at an example of a specific piece of equipment now in use by maintenance managers.

Automatic Pilot System

Virtually all airlines are using checkout equipment for their automatic pilot systems. Generally this piece of equipment comes under the category of semi-automatic type and is contained in a unit small enough to be termed a "suitcase tester." The semi-automatic tester for the DC-8 autopilot system accomplishes 99 distinct tests and is intended to pinpoint the particular "black box" or component within the installed system that should be removed and replaced in

order to bring the system into satisfactory operation.[1] These testers are available at the line maintenance stations for use by mechanics to analyze and trouble-shoot systems that have been complained about by flight crews.

These semi-automatic checkout units can be very valuable in finding troubles which can be corrected before they become "squawks" by a test flight crew. Using a $6 million airplane and a four-man flight crew as a test bed for an autopilot system with one, two or three re-runs of test flights to make sure that the trouble has been found and corrected, can be a terribly expensive way to operate.

Full Automatic Equipment Needed

Most of the semi-automatic equipment now in use is relatively "coarse" in nature. Usually only general indications are made. Too often, trouble-shooting with this equipment ends simply with replacing the biggest and most complex unit in the system because the law of averages says that this unit is likely to be the one with trouble in it.[2] Obviously this "shotgun" method is the most expensive possible to use. The cost in terms of

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[1] Aldrich, J. A., "Automatic Checkout Equipment for Airline Use," SAE Journal, Vol. 68, Dec. 1960, p. 39.

[2] Wood, 9 Dec. 1963, loc. cit.

aircraft out of service and thereby being a detriment instead of an earning power factor, the man-hours costs involved, the cost of the elaborate facilities that have to be provided in order to work on the aircraft at all and the tremendous cost of maintaining a stock of spare units of all sizes, shapes and descriptions in order to keep ever increasing supply lines full, is prohibitive.

What is needed is more elaborate and more delicate full automatic equipment for line maintenance. The concept should be in the nature of a van outfitted with sophisticated checkout equipment that can drive alongside the aircraft and plug in a cable to a receptacle on the side of the plane to checkout its systems in depth.

Aircraft now on the drawing boards should be designed to utilize sophisticated cybernetic maintenance equipment. The design concepts must take this need into full account, and the detailed engineering must recognize the requirement as the system evolves. Wiring circuits must be integral with the aircraft systems to permit the detailed analysis required. It is too late if we try to add it on or to squeeze it in later.

CHAPTER VII

FLIGHT DATA RECORDING FOR MAINTENANCE

Maintenance Analysis

All routine maintenance is now predicated upon time exposure of parts and equipment to usage and wear. It is true that information available from electronic data processing has put this problem more into focus -- that in case after case adjustments are being made to lengthen service life of airframes and parts. Often equipment and parts are being changed before failure by modified replacements. More efficiency and great savings have resulted.

Maintenance analysis, the "science" with which managers attempt to pinpoint where excess labor and material are being expended, cannot fully be developed until engineers can incorporate the other factors known to figure in wear and failure of parts. Temperature, stress and action have long been known to be important to the life of parts or systems.

Information from data processing systems have built a preponderance of evidence to indicate there is a definite correlation between the functioning or

malfunctioning of a component or system on an aircraft and other components and other systems on the same aircraft.

A simple case in point may be the landing strut on an aircraft or one of its many associated parts. The only way this part's life is determined now is by length of service and inspection for evidence of failure. (Inspections are even predicated upon time. Routine inspections are made after each flight with more detailed examinations being made after so many hours flight). More meaningful than time in evaluating wear would be the number of times the landing gear was activated (the plane could have been used on long flights with few landings or vice-versa). Other information would also be useful. Were the landings "hard" or "soft"? What were the loadings on landings? What vibrations were experienced? How much was the aircraft taxied, turned? With this information we would be in a better position to predict when the activating rod on the shimmy dampner would fail, and to predict if this failure would result in a blown tire and if the ultimate result would be a failure of the landing strut.

With thousands of parts to watch, statistical analysis of time and failure correlation has been about as much as management could digest until now. With the

automatic equipment and cybernetic systems now available other factors that contribute to failure can and must be considered.

Flight Data Recording

A comprehensive routine flight data recording system should be developed and installed on aircraft. Similar systems are now available and in use in aircraft research and testing programs.[1] The basic purpose of the maintenance recording would be to make available quickly to the maintenance manager and his staff a complete statement of the overall condition of an aircraft and all its component parts and accessory systems. Practically all operating parameters in an aircraft in the course of normal operation could be transduced into electrical form, then transferred to a magnetic or paper tape. Figure 9 shows a list of flight parameters considered significant for maintenance purposes. This tape could then be the direct input at a playback rate of one-hundred times recording speed to computers after each flight.

The tape recording would then furnish to a computer the current condition of the aircraft components

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[1]Flight recorders are now in routine use by airlines for a different purpose. Recordings made of a few basic parameters, protected by armored containers, are only analyzed in the event of a crash. No routine use is made of this valuable though scanty (in its present form) information.

1 Engine De-icing.
1 T.T.2 Air Temp.
  2nd stage compressor.
1 Oil temp.
1 Engine R.P.M. N2,
  high press. turbine.
2 Engine vibration.
1 Press. ratio.

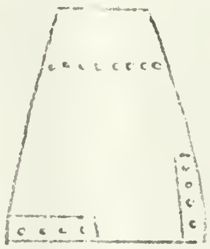
1 Oil quantity.
1 Fuel flow.
1 Oil press.
1 Engine R.P.M. N1,
  low press. turbine.
1 Oil pre-heating.
1 T.T.7 or exhaust gas
  temp. or jet pipe temp.

13 per engine x 4 ------------------ 52

1 Propeller pitch setting.
1 R.P.M.
1 Oil press.
1 Fuel flow.
1 Manifold air press.
1 Carburetor air temp.

1 Supercharged press.
1 B.M.E.P. or torque.
1 Cylinder head temp.
2 Engine vibration.
1 Oil temp.
1 Cowl flap setting.

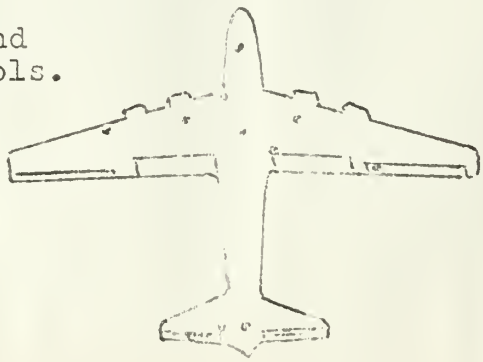
13 per engine x 4 ------------------ 52



1 Indicated air speed.
1 True outside temp.
1 Altitude.
1 Mach. No.
1 Cabin press.
4 Oil quantity.
1 Distance to fly.
1 Drift angle.

1 True air speed.
1 Heading.
1 Vertical acceleration.
1 Rate of climb.
4 Fuel quantity.
6 Electrical supply
  voltages and currents.
1 Off track distance.
1 Ground speed.

27 ------------------------ 27



20 Approx. misc. and
   emergency controls.
6 Hydraulic
  press.
4 Landing gear.
3 Flap setting.
10 Trim Tabs.
2 Rudder.

2 Wing de-icing.
4 Brakes.
8 Fuel controls.
2 Ailerons.
2 Elevator.

63 ------------------------ 63

Time Code Channel — G.M.T., Date, Flight No., Aircraft No. — Total 142

Figure 9.--List of Significant Flight Parameters for Maintenance and Their Source Location

by direct measurement and the actual service which the aircraft as a whole and its components in detail have undergone. Precise forecasts could be read directly from the computer as to when future maintenance action would become necessary by the detection of major and minor malfunctions which require immediate attention. The detection of failures occurring at key points in the mechanical, electrical and hydraulic systems of the aircraft would be diagnosed and indicated by the computer. As diagnosis normally represents a major proportion of the time taken in "trouble-shooting," there would be a significant savings in maintenance cost.

The advantage of recording for diagnosis is particularly important when failures occur that are associated with conditions of flight -- for example high altitude and air speed -- is difficult if not impossible to reproduce in ground "run-up" tests.

Obviously hours flown are not a reliable indication as to the overall service which an aircraft has undergone. The difference between the effects of flight in calm air and turbulent conditions on fatigue in the airframe structure is manifest. Just as obvious are effects of such factors as extremes of exhaust gas temperatures in turbine engines. Exceeding certain close limits for short periods may call for the replacement of at least the entire "hot" section of an engine. It should

be equally clear, therefore, that if certain conditions are destructive of an engine, then conditions less serious will affect the life of the engines in a marked degree.

The use of the flight recorders to supply source data as inputs to an integrated information system would represent a major breakthrough for aircraft maintenance managers. Shortly after each routine flight, managers would have available information herebefore available only to engineers in research work. Furthermore, this information after processing by computers would be presented in terms of management decisions.

Integration of the more meaningful data from flight recorder-computer systems with existing data collection systems, coupled with automatic checkout equipment should satisfy management needs for control, understanding and efficiency.

Flight recording systems and circuits for full automatic checkout equipment cannot be practically backfitted into present aircraft. Provisions for these systems should be incorporated into the design of aircraft and constructed as an integral part of the aircraft and its own systems.

CHAPTER VIII

CYBERNETIC MAINTENANCE -- A NECESSITY

Impact

Aircraft maintenance management problems are manifest. The costs involved are staggering. Recognizing the potential for management control of the computer, aircraft maintenance managers are turning to automated equipment and techniques for a solution to their problems.

Military aviation has initiated electronic data processing systems to give managers more meaningful and timely information with which to work. Many commercial airlines now use computers to make decisions for maintenance managers. These computers actually order part changes and schedule aircraft for inspections and overhauls. Computers store technical maintenance data for immediate access. Computers even help speed big complex aircraft through overhaul by assimulating and organizing the work. Semi-automatic checkout equipment similates operation and spots failures before they occur.

The impact of these cybernetic systems on aircraft maintenance has been better maintenance. For military aviation better maintenance has meant increased readiness,

lower cost and safer operations. For airlines, better maintenance has meant safer flights, more dependable timetables and rising profits.

Maj. Gen. Joseph R. Holzapple, USAF, Assistant Deputy Chief of Staff for Systems and Logistics, notes the new maintenance management program has paid dividends. The time for pulling a 600-hour inspection on the KC-135 tanker has been cut from nine days to two and a half. Inspection time on the B-52 has been dropped from eleven to under four days. Today the Air Force enjoys a significantly stronger force from an inventory that has increased little in numbers.[1]

The jet, although its basic engineering principle is far simpler than the piston, actually has more complex accessories and is more difficult to maintain than the piston airplane. Yet, since the introduction of cybernetic systems for maintenance, U.S. airline industry figures show jet engines are shut down in flight because of failure only one-sixth to one-seventh as often as piston engines.[2]

American Airlines reported mechanical trouble delayed only 4 per cent of their flights in 1963, against

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[1] Bamford, loc. cit.

[2] The Wall Street Journal, 11 Feb. 1964, p. 1.

7 per cent of the 1960 departures; they predict a further drop to 3.5 per cent in 1964.[1]

Trans World Airlines, Inc. now schedules a major airframe overhaul for each of its jets only once every two years. Before the introduction of their comprehensive computer parts accounting system, an airliner could go less than a year before requiring this $90,000 job.[2]

The time between major engine overhauls -- at a cost of about $100,000 on a four-engine airplane -- has been extended even more dramatically. Pratt and Whitney jet engines had to be overhauled after each 800 hours of operation in 1960. Today they are going 5,000 to 6,000 hours between overhauls on several major airlines.[3]

The results of these cybernetic systems have been sizable direct cost savings to the airlines. More important still, the airlines are now able to keep their jets in flight long enough to get the full benefit of their earning capacity. TWA, an international carrier, now can break even flying its planes with less than 40 per cent of their seats filled; in 1958 it required 60 per cent. American Airlines, a domestic carrier, can

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[1] Ibid.

[2] Ibid.

[3] Ibid.

break even now with 54 per cent of its seats filled, against 60 per cent in 1958.[1]

Managers may expect even more help in the future from flight recorders. These recorders will provide flight parameters of aircraft while flying as source data to computers for analysis and diagnosis. This innovation could be a major break through the time honored "hours flown" management concept.

Conclusions

Solutions to the maintenance problem are progressing in a traditional manner. Machines and computers are being substituted step-by-step for manual systems. This approach has been perhaps the result of entrusting the role of researching solutions to management's problems upon the manufacturers of computers. The computer manufacturer's research people frequently have determined the first applications of computers with no real idea of the problems involved or management's needs. Of course, these applications have been the ones easiest for the manufacturer to sell existing hardware. Initial results appear most impressive even as new problems and limitations appear.

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[1] *Ibid.*

The approach that must now be taken must be in terms of a wholly integrated cybernetic system. Now that the glamor of the computer hardware has faded into proper perspective, attention must be focused on management systems to best utilize technological innovations. Management needs to determine what information must flow and its relative value. It must devise new totally integrated systems, then seek out manufacturers to fulfill the hardware needs.

Aircraft maintenance managers and aircraft designers should collaborate on the design and construction of aircraft that can be a part of a fully integrated maintenance management system. Planners of aircraft in the future must incorporate use of full automatic checkout equipment and flight recording systems in their designs.

Future High Performance Aircraft

It is every bit as important to achieve maintainability and reliability in the supersonic transport as it is to obtain the Mach 3 performance. The economics of a Mach 3 airplane are based on the realization of three times the productivity of the present subsonic machines. If this objective is not realized, it probably will result in economic disaster for the airline and possibly for the specific airframe manufacturers.

It is imperative, therefore, that the next generation of air transports be designed with reliability and maintainability on equal basis with the speed and performance requirements. Quick and effective handling of all maintenance must be achieved to assume success of the supersonic airplane.

Maintainability and reliability in future military aircraft are not any less imperative. Reaction times are shrinking, constant readiness is a must. The task of maintaining a readiness posture is a gigantic one for military management.

Aircraft maintenance managers must rely on cybernetics for help. The high performance aircraft of the future must be designed and built for management and maintenance by machines.

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